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Effect of ionized plasma medium on radiation properties of open circuit microstrip rectangular resonator

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Abstract : Linearised hydrodynamic theory is used to investigate the effect of electro-acoustic and electromagnetic waves generated by a microstrip antenna in plasma media Several radiation properties of such resonator are studied by changing plasma to source frequency

Keywords : Microstrip resonator, plasma, electroacoustic waves, radiation conductance, radiation efficiency.

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1. Introduction

Microstrip antennas are finding more and more applications on modern satellites and rockets (Carver and Mink 1981, Post and Stephenson 1981) due to their light weight, better aerodynamic properties and low manufacturing cost. Antennas mounted on these vehicles encounter ionized plasma during their voyage in space and radiate electroacoustic waves in addition to the usual electromagnetic waves. The presence of electroacoustic waves changes the radiation properties of these antennas to a great extent.

Derneryd (1976, 1978), James and Wilson (1977), Chew *et al* (1980) and other workers studied radiation properties of different microstrip antenna structures in free space. This paper proposes to study the effect of the plasma medium on the radiation properties of the open circuit microstrip rectangular resonator.

2. Initial assumptions

For the purpose of present work, plasma is assumed to be warm, homogeneous lossless and nondrifting continuum of electrons and ions. For simplification, electrons are assumed to be the only effective component of plasma to respond to the time varying fields. The collisions of the electrons with neutral particles, the effect of sheath formation around the antenna and the presence of an external magnetic field are disregarded. To simplify the derivation, it is assumed that only the aperture portion of the antenna encounters the plasma

3. The radiating element

A microstrip line of length $2l$, conductor strip width W, substrate thickness h, substrate relative permeability and permittivity $\mu_r = 1$ and $\varepsilon_r = 1$ respectively lies in xz plane as shown in Figure 1. The waves guided by the microstrip are assumed to be transverse electromagnetic waves which are concentrated under the strip and incident on each aperture, where some power is radiated and the remainder is reflected back as a guided wave.

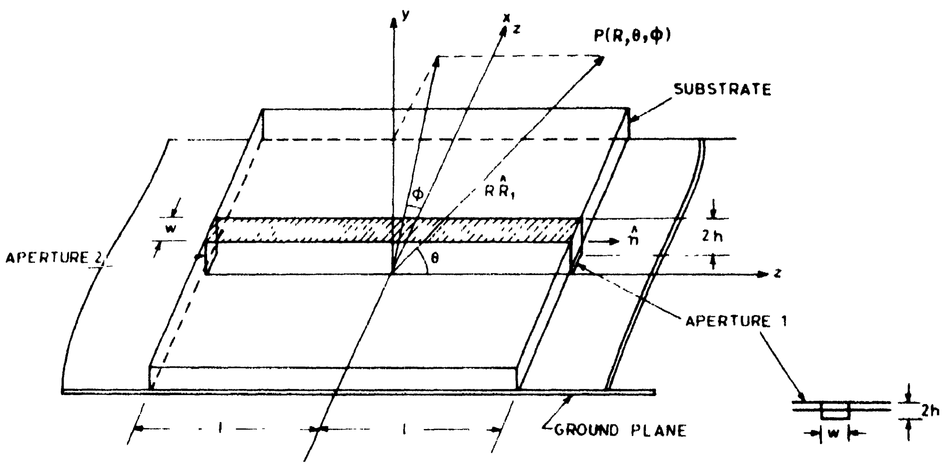

Figure 1. Geometry of the open circuit microstrip resonator

The transverse field in aperture 1 and 2 are :

Aperture 1	Aperture 2
$E = E_y \exp(-j\beta l)(1+\Gamma)\hat{y}$	$E = E_y \exp(j\beta l)(1+\Gamma)\hat{y}$
$H = H_x \exp(-j\beta l)(1-\Gamma)\hat{x}$	$H = H_x \exp(j\beta l)(1-\Gamma)\hat{x}$

(1)

here Γ is the complex reflection coefficient.

$$E_y = ZH_x, \qquad Z = Z_o / A\,(\varepsilon_{eff})^{1/2} \text{ and}$$

$$A = \left(1 - \frac{W_{pe}^2}{W^2}\right)^{\frac{1}{2}}$$

4. Radiation conductance

The power radiated by open circuit microstrip rectangular resonator through an upper half space is found by integrating complex Poynting vector over a closed surface. Expressions for radiation conductances in E.M. mode and L.P. mode are obtained using method suggested by Bhatnagar and Gupta (1984) and Freeston and Gupta (1971). These are

(i) For electromagnetic mode

$$G_e = \int_0^{2\pi}\int_0^{\pi}\left\{ \frac{A\beta_0^2 K^2 \varepsilon_{eff} W^2 Q^2}{480\pi^3} \cos^2\xi' \sin\theta \,(\cos^2\theta \sin^2\phi + \cos^2\phi) \right.$$

$$\left. + \frac{W^2 A^3 \beta_0^2 Q^2 \sin^2\xi'}{480\pi^3} \sin\theta \,(\sin^2\phi + \cos^2\theta + \cos^2\phi) \right\} d\theta\, d\phi \qquad (2)$$

here

$$Q = \left\{ \frac{\sin(\pi k_2 A \sin\theta \cos\phi)}{(\pi k_2 A \sin\theta \cos\phi)} \frac{\sin(2\pi k_1 A \sin\theta \sin\phi)}{(2\pi k_1 A \sin\theta \sin\phi)} \right\} \qquad (3)$$

$$h/\lambda_0 = k_1, \qquad W/\lambda_0 = k_2$$

$$\text{and } \xi' = \beta_0 l \left[A \cos\theta - (\varepsilon_{eff})^{\frac{1}{2}} \right]$$

(ii) For electroacoustic mode

$$Gp = \int_0^{2\pi}\int_0^{\pi} \frac{W^2\, 480\beta_p^2\, (1 - A^2)^2\, c^2 Q^2}{\pi A^3 W^2 Z^2} \cos^2 |(\beta_p \cos\theta \quad \beta) l| \sin\theta\, d\theta\, d\phi) \qquad (3)$$

here

$$Q' = \left[\frac{\sin\{(c/v_0)\, \pi k_2 A \sin\theta \cos\phi\}}{(c/v_0)\, \pi k_2 A \sin\theta \cos\phi} \frac{\sin\{(c/v_0)\, 2\pi k_1 A \sin\theta \cos\phi\}}{(c/v_0)\, 2\pi k_1 A \sin\theta \cos\phi} \right] \qquad (4)$$

and $\quad c/v_0 = 10^3$

Variation of radiation conductance with plasma parameter A is presented in Figure 2.

5. Radiation efficiency

The radiation efficiency of an antenna in the plasma medium is defined by Gupta (1972) as the ratio of useful power output in the plasma to the total power input

$$\eta = \frac{P_e}{P_e + P_p} \times 100\ (\%)$$

Here P_e and P_p are radiated power in E.M. mode and L.P. mode respectively. Variation of radiation efficiency of such resonator with the plasma paramcter A is shown in Figure 3.

Radiation conductance, and radiation efficiency of this type of antenna are calculated

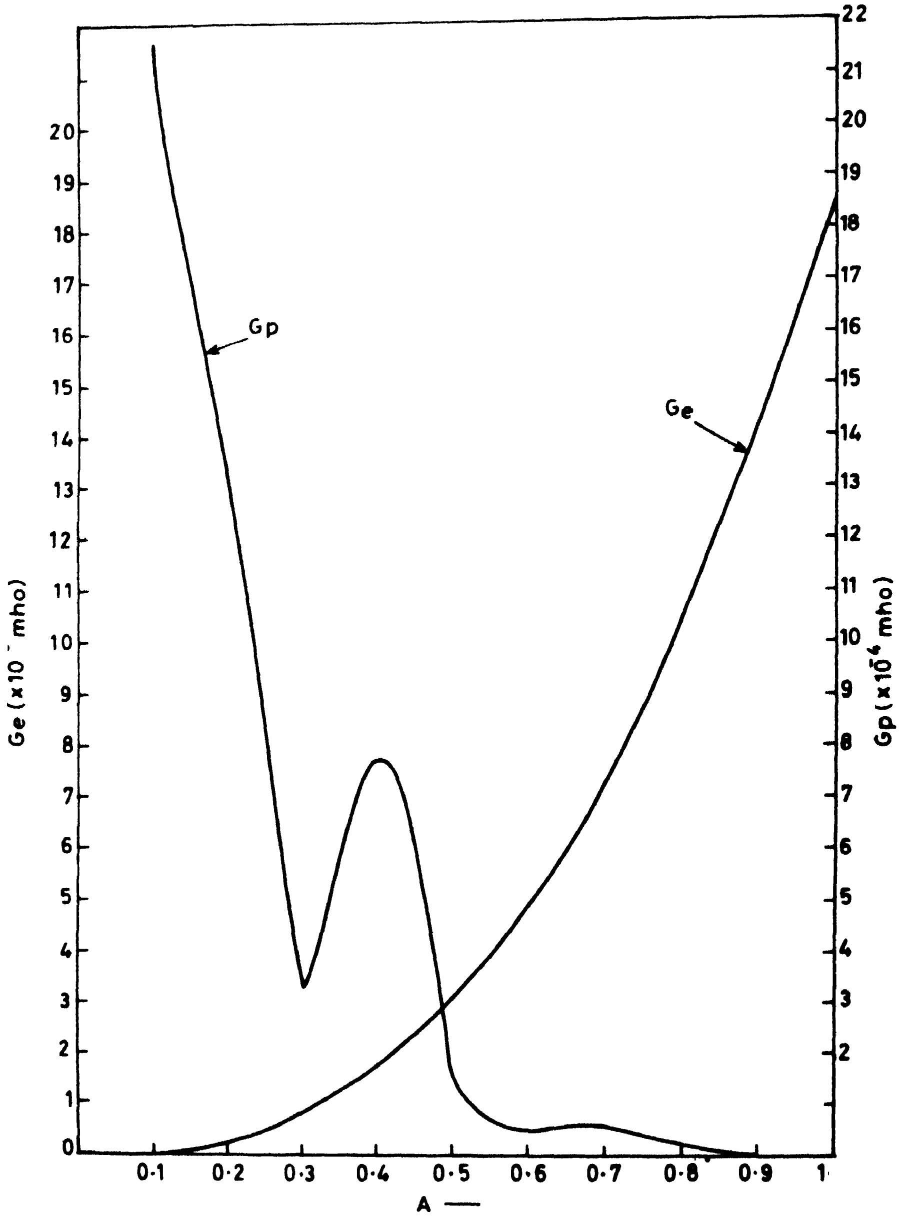

Figure 2. Variation of radiation conductances (G_e and G_P) with plasma parameter A.

for different values of A (l = 4.48 cm, h = 0.158 cm, W = 0.471 cm, ε_{eff} = 1.942 and f_r = 1.2 GHz.

6. Discussion and Conclusions

Radiation properties of an open circuit microstrip rectangular resonator are studied in ionized plasma medium by assuming that electrons are only effective components. Radiation conductance of such resonator in E.M. mode is maximum in free space and decreases sharply on increasing plasma frequency. On the other hand L.P. mode radiation conductance shows a non uniform behaviour probably due to excitation of electroacoustic waves. Net effect of these two radiated powers on efficiency of such resonator is a sharp decrease on increasing plasma frequency. Therefore this type of resonator is suitable for application in space when plasma frequency is small.

The effect of plasma medium on radiation properties of microstrip resonator is significant and needs experimental verification.

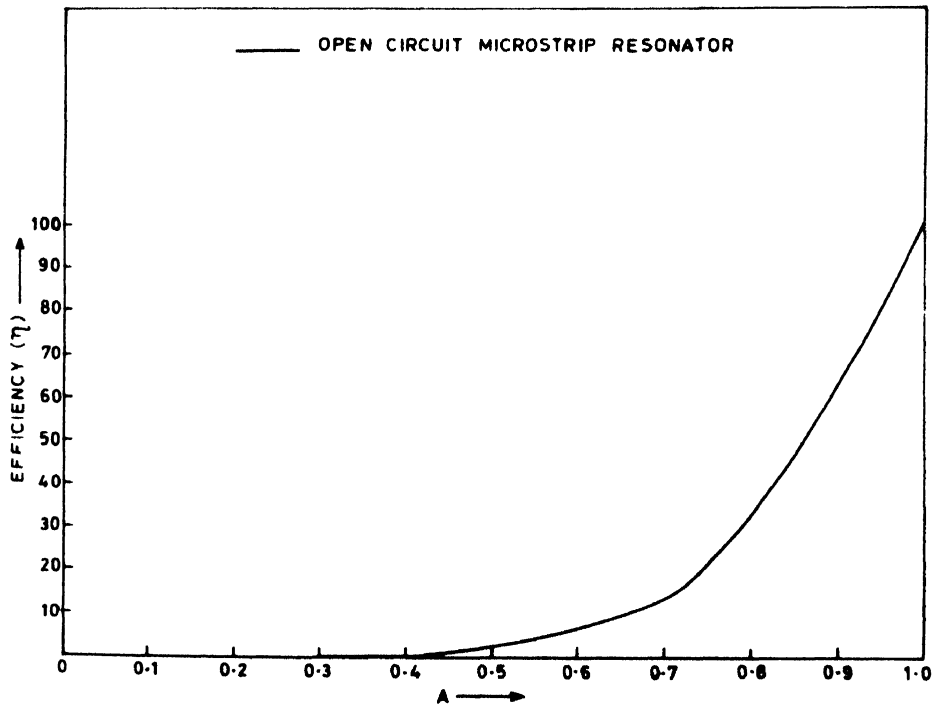

Figure 3. Variation of radiation efficiency with plasma parameter A

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References

Bhatnagar D and Gupta R K 1984 *J Inst Telecomn Engrs* **30** 92

Carver K R and Mink J W 1981 *IEEE Trans Antenna and Propagation* **29** 1

Chew W C, Kong J A and Shen L C 1980 *J Appl Phys* **51** 3907

Derneryd A G 1976 *IEEE Trans Antenna and Propagation* **24** 846

— 1978 *IEEE Trans Antenna and Propagation* **26** 532

Freeston I L and Gupta R K 1971 *Proc IEE* **118** 633

Gupta R K 1972 *Indian J Radio Space Phys* **1** 281

James J R and Wilson G J 1977 *Microwave Opt Acoust* **1** 165

Post R E and Stephenson D T 1981 *IEEE Trans Antenna and Propagation* **29** 129